(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 563 724 A1**

# (12) EUROPEAN PATENT APPLICATION

(21) Application number: 93104634.6

(51) Int. Cl.[5]: F25D 21/02

(22) Date of filing: 22.03.93

(30) Priority: 30.03.92 IT MI920755

(43) Date of publication of application: 06.10.93 Bulletin 93/40

(84) Designated Contracting States: DE FR GB

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## (54) Method and device for evaluating frost formation on an evaporator in a refrigerator, in particular of the forced-air circulation type.

(57) A method for evaluating frost formation on a usual evaporator (102) in a refrigerator (1), in particular of the forced-air circulation type, comprising a cabinet containing at least one compartment (100), in which the evaporator (102) is located, and at least one fan (3) arranged to generate air circulation within said compartment (100) and cooperating with a usual conveying member (106) for conveying said air from said compartment (100) onto the evaporator (102) so that the air is again cooled. The method comprises evaluating the variation in the flow rate of the air which strikes the evaporator (102), and on the basis of this determining the quantity of frost present on the evaporator (102), then defrosting this latter if necessary.

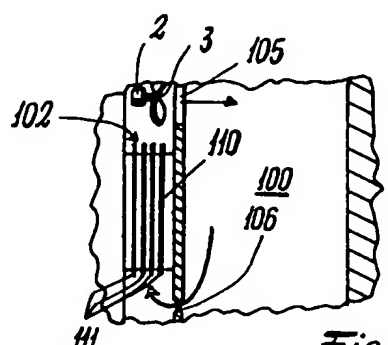


Fig. 2

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This invention relates to a method for evaluating frost formation on an evaporator in a refrigerator, in particular of the forced-air circulation type and comprising a cabinet containing one or more temperature-controlled compartments provided with their own access doors and arranged to contain food during its preservation, there being provided on the wall of the compartment in which the evaporator is located at least one heating element which when activated defrosts the evaporator, and a fan driven by a usual electric motor connected to an electrical power line for circulating air through the evaporator and for ventilating the compartment or compartments via usual ducts provided within said cabinet, said fan, to achieve said circulation, cooperating with a usual conveying member to direct the air circulating within said compartment or compartments onto the evaporator so that the air is again cooled.

As is well known, during the use of such a refrigerator frost forms (for known reasons) on the evaporator surface, resulting in a reduction in heat transfer between this surface and the air which grazes it. The evaporator performance is consequently reduced, with obvious drawbacks.

To free the evaporator of the layer of frost which forms on it, there is associated with it a usual electrical resistance element (or other equivalent heating element) which when current flows through it heats the frost and converts it into water.

This is then removed from the evaporator via a suitable channel.

Said defrosting is effected in various ways. For example, the evaporator may be defrosted automatically after a fixed period of operation of the usual refrigeration circuit of the refrigerator (or of the known compressor of this circuit). However this method of defrosting does not take account of whether it is really necessary to remove frost from the evaporator at that time, hence defrosting may take place when there is no real need for it (with obvious disadvantages in terms of refrigerator operation).

Methods and devices for sensing the presence of frost on the evaporator are known (such as those using optical sensing means), these then, on the basis of this, either activating or not activating the heating element associated with the evaporator (while at the same time interrupting the operation of the refrigeration circuit of which this latter forms part). These methods and devices however have a level of implementation and/or construction cost which negatively affects the overall cost of the refrigerator. In addition, said methods and devices do not allow accurate measurement of the frost thickness on the evaporator, and are able only to sense whether a layer is present on a given portion of it. Consequently, operation of the heating element associated with the evaporator, based on the sensing of frost on it, may sometimes be unnecessary, so negatively affecting the refrigerator performance.

An object of the present invention is to provide a method for sensing the presence of frost on the evaporator by which this latter is defrosted only if it is covered with a layer of frost to the extent of changing its heat transfer characteristics.

A further object is to provide a method of the aforesaid type which is of low implementation cost and which enables the evaporator defrosting process to be optimized.

A further object of the invention is to provide a device for evaluating the thickness of frost on an evaporator which is of simple construction, of reliable use and operation, and is able to activate the heating element associated with the evaporator only when on the surface of this latter there is a quantity of frost present such as to change its heat transfer characteristics.

These and further objects which will be apparent to the expert of the art are attained by a method of the aforesaid type, characterised by evaluating the variation in the flow rate of the air grazing the evaporator with respect to a flow rate reference value, determining the quantity of frost present on the evaporator surface on the basis of this evaluation, and then if necessary activating the heating element associated with the evaporator.

Said method is implemented by a device applied to a refrigerator of the aforesaid type, characterised by comprising switch means connected into the fan power line, and sensor means for sensing an intrinsic characteristic of the fan and generating a signal relative to the fan operating condition, said signal being fed to comparison and control means which compare it with a reference signal and on the basis of this comparison act on the switch means to change the fan operating conditions, and on the heating element to activate it and hence defrost the evaporator.

Said method is also implemented by a device applied to a refrigerator of the aforesaid type, characterised by comprising means for measuring the flow rate of the air circulated through the compartment by the fan and cooled by the evaporator, said means generating an electrical signal based on the measured flow rate, said means, on the basis of this comparison, acting on switch means connected into the fan power line to alter the fan operating conditions, and activating the heating element to defrost the evaporator.

The present invention will be more apparent from the accompanying drawing, which is provided by way of non-limiting example and in which:

Figure 1 is a schematic view of a refrigerator constructed in accordance with the invention;

Figure 2 is a section on the line 2-2 of Figure 1;
Figure 3 is a block diagram of a first embodiment of a device according to the invention;
Figure 4 is a block diagram of a second embodiment of a device according to the invention;
Figure 5 is a block diagram of a third embodiment of a device according to the invention;
Figure 6 is a block diagram of a fourth embodiment of a device according to the invention;
Figure 7 is a schematic section on the line 2-2 of a refrigerator provided with a fifth embodiment of a device according to the invention;
Figure 8 is a block diagram of the embodiment of Figure 7; and
Figure 9 is a simplified block diagram of a sixth embodiment of the invention.

With reference to Figures 1 and 2, a refrigerator (for example a domestic refrigerator) is indicated overall by 1 and comprises a fan 3 driven by a motor 2 powered via an electrical line 4 by a known control member 5 (such as a static switch controlled by a usual control unit, not shown, connected to a known timer which controls the operation of the refrigerator). The fan 3 is contained in a compartment 100 provided in the cabinet 1A of the refrigerator, in correspondence with an evaporator 102, and can also feed air through a duct 103 if the refrigerator is of the type comprising several superposed compartments, said duct terminating in at least one of these compartments. The fan also feeds air directly into the compartment 100 via an aperture 105 provided in correspondence with the evaporator 102. In proximity to this later there is also a usual air conveying member 106 through which air can be drawn from the compartment 100 and onto the evaporator via an aperture 107. The evaporator comprised a body 110 provided with fins 111 in known manner.

Specifically (see Figure 3), the motor 2 of the fan 3 is connected to the control member 5 by a return line 4A, said control member being powered in known manner by mains voltage $V_R$. A feedback branch 6 connects the member 5 to an integrator member or circuit 8 connected by electrical branches 9 and 10 to the ends 11 and 12 of the motor 3. The integrator member or circuit (of any known type) measures the feed voltage across the ends 11 and 12 of the motor 3 and generates in the feedback branch a control signal $V_A$ which enables the member 5 to maintain the feed voltage of the motor 3 constant in known manner.

A tachometer dynamo 15 (or a control circuit comprising such a dynamo) measures the r.p.m. of the motor 3. The dynamo 15 is connected to a digital/analog converter 16 connected to a non-inverting input 17 of any known comparator circuit or member 18.

The inverting input 19 of the circuit or member 18 receives a reference signal $V_E$ corresponding to a very thin layer of frost on the evaporator, ie unable to significantly impede the air flow traversing the evaporator 102. The output 20 of said circuit 18 is connected to a usual heating element 21 located in correspondence with the evaporator 102. Said comparator circuit or member 18 also controls the opening of a switch 23 in the line 4, for example via a usual bistable element (not shown) or an analogous relay 28 connected to its output 20.

The switch 4 is normally closed during normal operation of the refrigerator.

The implementation of the method according to the invention will now be described in relation to the control of the fan motor 2 connected to the circuit 25 shown in Figure 3.

During normal refrigerator operation, the member 5 controls the operation of the motor 2 in any known manner. As stated, via the integrator circuit 8 the member 5 controls the power supply to the motor 2 such that it is operated at constant voltage.

This member is also connected by an electrical branch 29 to a usual relay 30 arranged to control a switch 31 in the output 20 of the circuit 18 towards the heating element 21 (as shown in Figure 3).

For known reasons, during the refrigerator operation frost forms on the evaporator and with the passage of time reaches a significant thickness such as to reduce the normal flow of air along the evaporator fins 111. This changes the fan r.p.m., which tends to "rotate idly". This increase is sensed by the tachometer 15.

During normal refrigerator operation with no frost on the evaporator 102, the tachometer generates a signal $V_B$ (digital) of a value only slightly different from or lower than the signal $V_E$.

Consequently when the signal $V_B$, made analog, reaches the comparator member or circuit 18, this latter generates no output signal.

When frost forms on the evaporator, the signal $V_B$ increases possibly considerably with respect to the signal $V_E$.

The comparison between these two by the member 18 consequently results in this latter generating a signal $V_C$ (analog or digital) which both causes the switch 23 to open and the heating element 21 to operate. In this manner the fan 3 stops and the evaporator defrosting proceeds.

Advantageously the member 5 senses the opening of the switch 23 in known manner and acts (directly or indirectly) on the usual compressor (not shown) of the refrigeration circuit of which the evaporator 102 forms part, and halts it. The operation of the refrigerator consequently ceases.

After a predetermined time period sufficiently long to enable the evaporator to defrost, the mem-

ber 5 acts on the relay 30, which opens tile switch 31 (normally closed). This interrupts the operation of the heating element 21.

At substantially the same time (or possibly sooner), the relay 28 closes the switch 23 in known manner. The member 5 can therefore again control the operation of the fan 3 and reactivate the compressor to return the refrigerator to operation.

Alternatively the frost sensor (not shown) senses that there is no longer frost on the evaporator.

One particular embodiment of the invention has been described.

Modifications are however possible, such as the tachometer not generating a digital signal but instead directly generating an analog signal which is compared continuously by the circuit or member 18 with the reference signal (also analog in this case).

This latter can be fixed or variable, and be set by usual electrical members such as a trimmer or other known member.

The member 5 can also be a usual microprocessor circuit and effect the comparison between the signals $V_B$ and $V_E$. This can be done either continuously during the entire period of operation of the refrigerator 1 or cyclically at particular times.

Figure 4, in which parts corresponding to those of Figure 3 are indicated by the same reference numerals, shows a further embodiment of the invention.

In this figure the feedback branch (by which the member 5 controls the operation of the motor 2 at a constant r.p.m.) is connected directly to the digital/analog converter 16 or to the tachometer 15 if this generates an analog signal $V_B$ or if the member 5 is able to operate directly on a digital signal.

A shunt resistor 40 is connected into the return branch 4A from the motor 2 to the member 5 in series with this motor, and has its ends 41, 42 connected to electrical branches 43, 44 leading to the integrator circuit 8, and to branches 45, 56 leading to a known current member or sensor 47. The circuit 8 and the sensor 47 are connected by electrical branches 48, 49 respectively, to a usual multiplier 50. These branches carry signals corresponding to the voltage and to the current absorbed by the motor 2 respectively.

Consequently the multiplier 50 generates in its output branch 51 a signal $V_D$ proportional to the power absorbed from the mains by the motor 2 during its operation. The branch 51 terminates at the non-inverting input of the circuit or member 18.

During the operation of the refrigerator 1, the signal $V_C$ is substantially close to or less than the signal $V_E$ (in value).

Consequently the comparison between the two signals does not cause the circuit 18 to generate any output signal $V_C$.

When an excessive quantity of frost forms on the evaporator 102, this changes the voltage and current absorption by the motor 2.

Consequently the absorbed power of this latter changes. The signal $V_D$ therefore changes to a value which can be considerably different from $V_E$. This, as already described, leads to generation of the signal $V_C$, stoppage of the motor 2 and defrosting of the evaporator. After a suitable time the system returns to the initial conditions, as already described in relation to Figure 3.

Figure 5 shows a further embodiment of the invention. In this figure, parts corresponding to those of the previously described figures are indicated by the same reference numerals.

In this case, the the operation of the motor 2 is again controlled at constant r.p.m. by the tachometer dynamo 15. Frost formation is however evaluated via the integrator circuit 8 or via the variation in the feed voltage of the motor 2 as measured by the circuit 8.

In the case of Figure 5, the creation of an excessive frost layer leads to an increase in the voltage absorbed from the mains by the motor 2 (operating at constant r.p.m.). The circuit 8 consequently generates towards the circuit 18 a signal $V_G$ which is considerably different from the signal $V_E$ (which it approaches or falls below during normal operation of the refrigerator 1 with a frost layer on the evaporator which is less than that which would considerably hinder the air flow traversing the evaporator or reduce the cross-section of the passage at the evaporator through which said air flows).

In this case the circuit 18 acts in the described manner, to halt the motor 2 and activate the heating element 21.

Following defrosting of the evaporator, the motor 2 is again operated and the heating element 21 switched off (as already described).

Figure 6 shows a further embodiment of the invention. In this figure, parts corresponding to those of the previously described figures are indicated by the same reference numerals.

In Figure 6 there is no control feedback to the fan motor because in this case the motor used is a known high-efficiency motor with a very constant torque-r.p.m. characteristic. This motor, indicated by 2A in the figure, operates at constant voltage and known r.p.m. It is "current" controlled, ie the resistor 40 is connected into the branch 4A and its ends 41, 42 are connected to branches 45, 46 terminating in a known current sensor 47.

During refrigerator operation, if the frost thickness on the evaporator is unable to substantially

hinder the flow of air grazing the evaporator, the current sensor 47 generates a signal $V_H$ substantially close to or less than the threshold signal $V_E$.

When a considerable frost layer forms on the evaporator 102 the signal $V_H$ becomes considerably greater than the signal $V_E$. The circuit 18 therefore generates the signal $V_C$, which results in stoppage of the motor 2 and operation of the heating element 21.

After the evaporator has been defrosted, the motor is again operated in the described manner and the element 21 switched off.

With reference to Figures 3 to 6, devices for implementing the method of the invention have been described in which the frost on the evaporator is evaluated indirectly by measuring the variation in a characteristic of the motor 2 of the fan 3 (r.p.m., absorbed power, absorbed voltage or current).

However the method of the invention can be implemented by direct measurement of the flow rate of the air leaving the aperture 105 (arrow F) or returning to the evaporator 102 through the aperture 106 (arrow G).

Embodiments of devices which enable the method to be implemented in this form are shown in Figures 7 to 9. In these figures, parts corresponding to those of the previously described figures are indicated by the same reference numerals.

Figures 7 and 8 show a flow rate measurement member 90 positioned in correspondence with the aperture 105. This member is a usual anemometer 91 connected to a control circuit 92. This latter receives a signal $V_M$ generated by the anemometer (a function of the air flow rate through the aperture 105) and compares this with a reference signal $V_{RIF}$ corresponding to a minimum acceptable air flow rate (corresponding to a maximum acceptable frost quantity on tile evaporator 102). If $V_M$ is less than $V_{RIF}$ (ie the frost has reduced the air flow leaving the aperture 105 to too low a value), the circuit 92 operates the switch 23 to halt the motor 2, and operates the heating element 21. The evaporator is therefore defrosted and the member 5 simultaneously halts the operation of the refrigerator 1, in the described manner.

When defrosting is complete the member senses that the frost has been removed from the evaporator and causes the circuit 92, via an electrical branch 93, to halt the operation of the element 92 and close the switch 23. The member 5 hence reactivates the refrigerator.

In Figure 9, two pressure sensors 94 and 95 are positioned in correspondence with the apertures 105 and 106 to determine the flow rate of the air which has already grazed the evaporator and that of the air which returns to it. In this case, the circuit 92 senses a pressure difference between the apertures 105 and 106.

If the frost reduces the air flow this pressure difference decreases. The circuit 92 measures this (for example by making a usual comparison between the signals $V_O$ and $V_P$ from the sensors, this latter being considered the reference signal) and acting on the heating element 21 and switch 23 as already described in relation to Figures 7 and 8.

When defrosting is complete, the motor is returned to operation and the element 21 switched off in the previously described manner.

Various embodiments of the invention have been described. However further embodiments are possible, to be considered as falling within the scope of the present document.

For example, the anemometer 91 can be replaced by a heated wire grazed by the air leaving the aperture 105. This wire involves a current and generates across its ends a potential difference which is proportional to the cooling which it undergoes as a result of the air striking it, so changing its resistance. As the flow rate of the air striking it changes, so does the potential difference across its ends. By measuring this (in any known manner, for example by a circuit analogous to the circuit 92 of Figure 8), when the potential difference reaches a predetermined value the control circuit associated with the wire acts to halt the motor and activate the heating element.

## Claims

1. A method for evaluating frost formation on an evaporator in a refrigerator, in particular of the forced-air circulation type and comprising a cabinet containing one or more temperature-controlled compartments provided with their own access doors and arranged to contain food during its preservation, there being provided on the wall of the compartment in which the evaporator is located at least one heating element which when activated defrosts the evaporator, and a fan driven by a usual electric motor connected to an electrical power line for circulating air through the evaporator and for ventilating the compartment or compartments via usual ducts provided within said cabinet, said fan, to achieve said circulation, cooperating with a usual conveying member to direct the air circulating within said compartment or compartments onto the evaporator so that the air is again cooled, said method being characterised by evaluating the variation in the flow rate of the air grazing the evaporator (102) with respect to a flow rate reference value, determining the quantity of frost present on the surface of the evaporator (102) on the basis of this evaluation, and then if necessary activating

the heating element (21) associated with the evaporator.

2. A method as claimed in claim 1, characterised in that the variation in the air flow rate is measured directly.

3. A method as claimed in claim 2, characterised in that the direct measurement of the air flow rate is made as the air enters the compartment (100) of the refrigerator (1).

4. A method as claimed in claim 2, characterised in that the direct measurement of the air flow rate is made by comparing the difference between the pressure of the air fed into the refrigerator compartment (100) and that of the air returning from said compartment to the evaporator (102).

5. A method as claimed in claim 1, characterised in that the flow rate variation is evaluated indirectly by measuring the variation in an intrinsic characteristic of the motor (2) operating the fan (3).

6. A method as claimed in claim 5, characterised in that the measured characteristic is the voltage absorbed from the mains by the motor (2) when operating at a constant r.p.m.

7. A method as claimed in claim 5, characterised in that the measured characteristic is the current absorbed from the mains by the motor (2) when operating at a constant r.p.m.

8. A method as claimed in claim 5, characterised in that the measured characteristic is the power absorbed from the mains by the motor (2) when operating at a constant r.p.m.

9. A method as claimed in claim 5, characterised in that the measured characteristic is the r.p.m. of the motor (2) when operating at constant voltage, and hence of the fan (3).

10. A device for implementing the method claimed in claim 1, characterised by comprising switch means (23) connected into the line (4) powering the motor (2) of the fan (3), sensor means (15, 8, 47, 50) for sensing an intrinsic characteristic of the fan (3) or of its motor (2) and generating a signal ($V_B$, $V_D$ , $V_G$, $V_H$) relative to the fan operating condition, said signal being fed to comparison and control means (18) which compare it with a reference signal ($V_E$) and on the basis of this comparison act on the switch means (23) to change the operating conditions of the fan (3), and on the heating element (21) to activate it to achieve defrosting of the evaporator (102).

11. A device as claimed in claim 10, characterised in that the fan motor (2) operates at constant voltage and the sensor means are a tachometer dynamo (15).

12. A device as claimed in claim 10, characterised in that the fan motor (2) operates at constant r.p.m. and the sensor means are a known integrator circuit (8).

13. A device as claimed in claim 10, characterised in that the fan motor (2) operates at constant r.p.m., said motor being preferably of high-efficiency type, and the sensor means are a known current measurement member (47) connected to the ends (41, 42) of a resistor (40) connected in series with said motor (2).

14. A device as claimed in claim 10, characterised in that the fan motor (2) operates at constant r.p.m. and the sensor means are a multiplier member (50) connected to an integrator circuit (8) measuring the voltage absorbed from the mains by the motor (2), and to a current measurement member (47) measuring the current absorbed from the mains by the motor (2), said multiplier member (50) generating a signal ($V_D$) fed to the comparison means (18) and corresponding to the power absorbed from the mains by said motor (2).

15. A device as claimed in claim 10, characterised in that the comparison means are a comparator circuit (18) or an equivalent member.

16. A device as claimed in claim 15, characterised in that the comparison means are connected to an actuator member (28) for opening or closing the switch means (23).

17. A device as claimed in claim 10, characterised in that the operation of the fan motor (2) is controlled by a control member (5) which preferably controls the operation of the refrigerator.

18. A device as claimed in claim 17, characterised in that the control member (5) is operationally connected to switch means (31) in an electrical line (20) connecting the comparison means (18) to the heating element (21).

19. A device as claimed in claim 17, characterised in that the control member is a microprocessor circuit.

**20.** A device for implementing the method claimed in claim 1, characterised by comprising means (91; 105; 106) for measuring the flow rate of the air circulated by the fan (3) through the compartment (100) and cooled by the evaporator (102), said means (91; 105; 106) generating an electrical signal based on the measured flow rate, said signal being fed to comparison and control means (92) which compare it with a reference signal, said means (92), on the basis of this comparison, acting on switch means (23) connected into power line (4) to the fan motor (2) to change the fan operating conditions, and activating the heating element (21) to defrost the evaporator.

**21.** A device as claimed in claim 20, characterised in that the flow rate measurement means are an anemometer (91) located in correspondence with the region (105) in which the cold air is fed into the refrigerator compartment (100).

**22.** A device as claimed in claim 20, characterised in that the flow rate measurement means are a conductor of wire form maintained at relatively high temperature and involving current, said wire being positioned in correspondence with the region (105) in which air is fed into the refrigerator compartment (100).

**23.** A device as claimed in claim 20, characterised in that the measurement means are pressure sensors (94, 94) positioned in correspondence with the passages (105, 106) through which the air passes to the compartment (100) and from this latter to the evaporator (102).

**24.** A device as claimed in claims 20 and 23, characterised in that the reference signal is the signal ($V_P$) generated by the pressure sensor (95) positioned in correspondence with the passage (106) though which the air passes towards the evaporator (102).

**25.** A device as claimed in claim 20, characterised in that a circuit (5) for controlling the operation of the fan motor (2A) is connected to and operates on the comparison means (92).

**26.** A device as claimed in claim 20, characterised in that the reference signal corresponds to the flow rate of the air grazing the evaporator (102) when this is substantially free of frost.

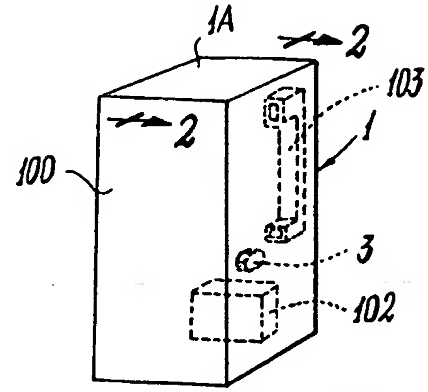


Fig. 1

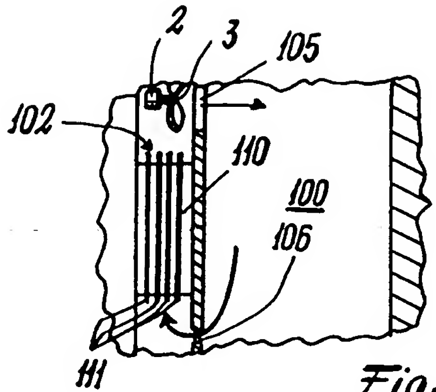


Fig. 2

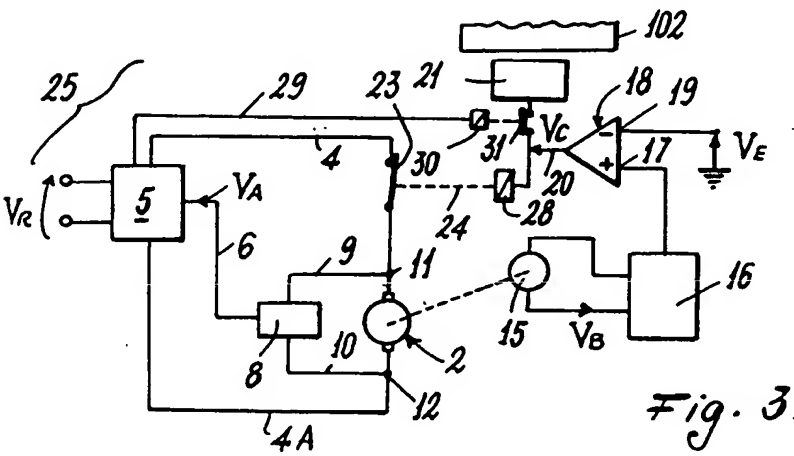


Fig. 3

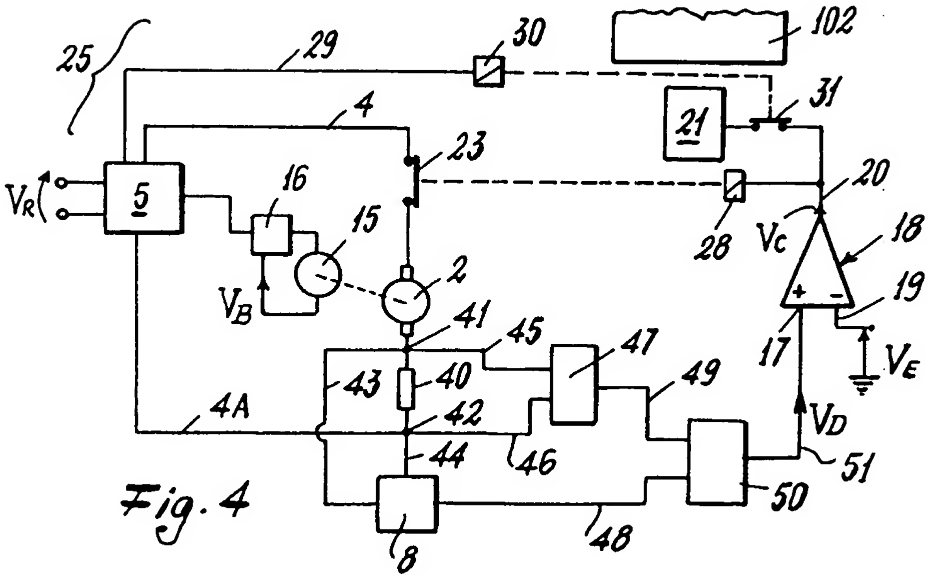


Fig. 4

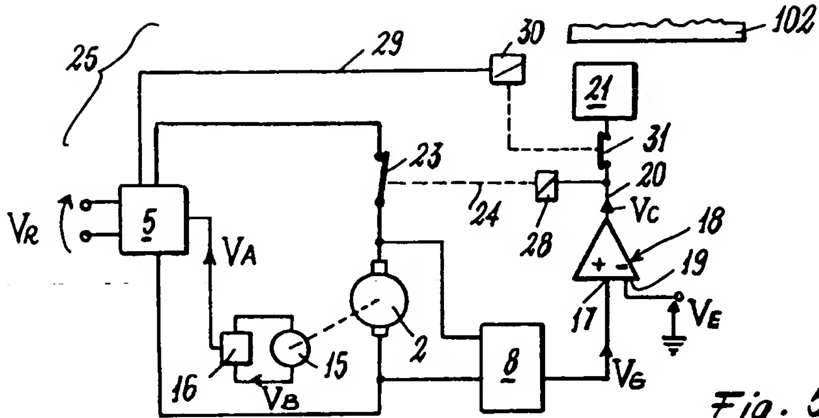


Fig. 5

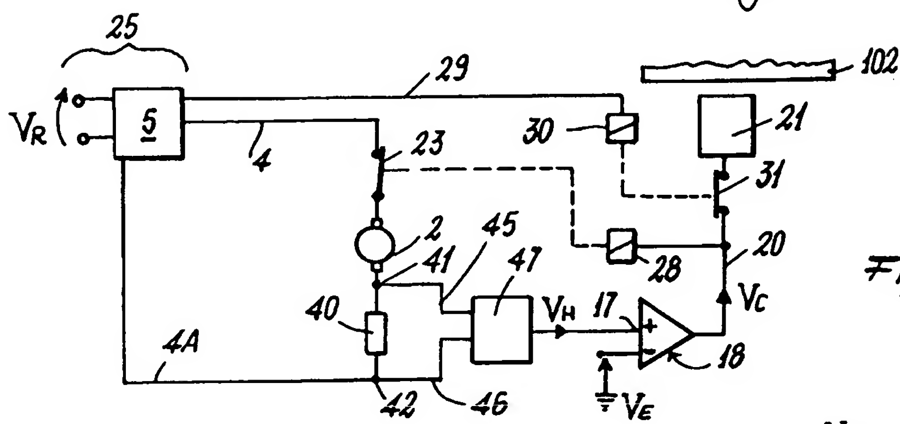


Fig. 6

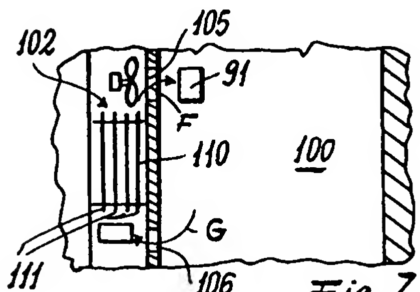


Fig. 7

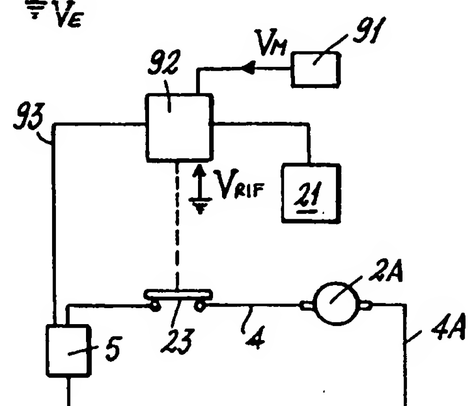


Fig. 8

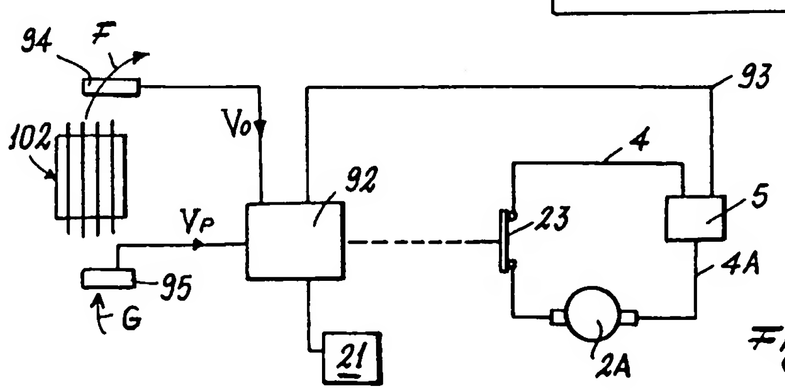


Fig. 9

European Patent Office

# EUROPEAN SEARCH REPORT

Application Number

EP 93 10 4634

## DOCUMENTS CONSIDERED TO BE RELEVANT

| Category | Citation of document with indication, where appropriate, of relevant passages | Relevant to claim | CLASSIFICATION OF THE APPLICATION (Int. Cl.5) |
|---|---|---|---|
| X | US-A-3 728 867 (JARRETT) | 1,2,4, 20,23-26 | F25D21/02 |
| Y | * column 2, line 33 - column 6; figure 1 * | 5,7,10, 13,15, 16,21 | |
| Y | PATENT ABSTRACTS OF JAPAN vol. 010, no. 356 (E-459)29 November 1986 & JP-A-61 154 496 ( MITSUBISHI ELECTRIC ) * abstract * | 5,7,10, 13,15,16 | |
| Y | GB-A-2 033 582 (DART AUSSCHANK RATIONALISIERUNGSTECHNIK) * Abstract * | 21 | |
| A | US-A-4 806 833 (YOUNG) * column 6, line 9 - line 35; figures 1,5 * | 1,5,9, 10,11 | |

TECHNICAL FIELDS SEARCHED (Int. Cl.5)

F25D
G05D

The present search report has been drawn up for all claims

| Place of search | Date of completion of the search | Examiner |
|---|---|---|
| THE HAGUE | 22 JUNE 1993 | BAECKLUND O.A. |

CATEGORY OF CITED DOCUMENTS

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